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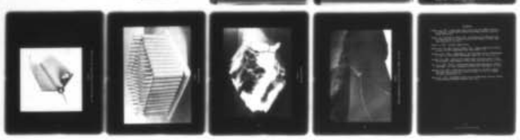

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TAGGING OF ARCTIC ICEBERGS

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U. S. Coast Guard Research and Development Center
Avery Point, Groton, Connecticut 06340

January 1978

FINAL REPORT

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ABSTRACT

16. Abstract

An air-deployable iceberg tagging system has been developed for use from a C-130 aircraft. The system consists of a steel dart with a trailing buoyant line which can be attached to a floating instrument package. The system allows for considerable melting and rolling of the iceberg, but cannot survive calving in the vicinity of the dart.

ABSTRACT

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METRIC CONVERSION FACTORS

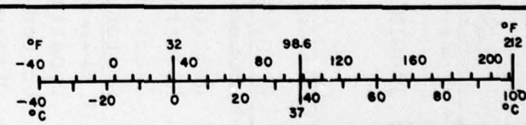
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit *temperature*	5/9 (after *subtracting* 32)	Celsius *temperature*	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

The icebergs which calf from the Greenland glaciers have threatened the North Atlantic fisherman and mariner since the rich fisheries of the Northwestern Atlantic were discovered and ships began plying the great circle route between the east coast of North America and the northern coast of Europe. Long before the TITANIC disaster forcefully brought the hazards of icebergs to public attention through the loss of over 1500 lives, ship collisions with icebergs were not unknown. In 1841 the ship ISABELLA struck an iceberg and sank on the 9th of May. The crew barely had time to take to the boats, without water, provisions, or clothing. The sinking took place at latitude 42-02N, longitude 43-45W. The years 1841 and 1842 appear to have been unusually heavy ice years with a ship reporting upward of 300 icebergs in a single crossing (Redfield, 1845). The SS PACIFIC hit an iceberg and sank with the loss of 186 lives on 29 January 1856. The SS CITY OF BOSTON was lost with 177 souls on 30 January 1870.

Prior to the earliest use of the shipboard radio, in the first few years of the twentieth century, the fate of a ship would probably remain unknown when it failed to reach port. Some of these reported missing were certainly the victims of floating ice. This, of course, all changed when on the night of 14 April 1912 the TITANIC struck an iceberg and sank 1000 miles east of New York. The TITANIC disaster was one of the first to be reported by ship's radio, causing an immediate public sensation. This tragedy led to the creation of the International Ice Patrol (IIP) which has been operated by the U.S. Coast Guard since 1914. Each spring, IIP patrols the waters of the Grand Banks of Newfoundland and publishes twice daily ice bulletins for the benefit of mariners. Even with the best of information, modern equipment, radar, ice reinforcement, and skilled crews, disasters can still occur as on the 30th of January 1959 when the M/V HANS HEDTOFT struck an iceberg in the fog forty miles south of Cape Farewell, Greenland, which was far to the north of the IIP operations area. The ship was specially constructed for the Greenland trade and was returning from her maiden voyage. All 95 crew and passengers were lost without a trace.

The IIP has used oceanographic cutters, aircraft, and satellites with considerable success in an effort to furnish accurate and timely iceberg position data to ships traversing the Grand Banks region. This effort has been hampered by chronic bad weather and persistent fog as well as the relative inaccessibility of this area of the ocean from staging areas.

2.0 PAST TAGGING EFFORTS

All of the early work with iceberg drift and deterioration was with the drift and deterioration of the entire population of icebergs because of IIP's limited detection capability (Cheney, 1951). When icebergs were near the southern, western, or eastern boundaries of the defined ice-infested area, they were considered highly dangerous to shipping and a surface patrol vessel would be assigned to follow these icebergs until they melted (Lenczyk, 1965). Only this continuous contact could assure that the iceberg being tracked remained the same piece of ice. Because of the changes in the icebergs' shape by calving, rolling, and melting, even repeated aircraft flights could not make positive identification in most cases (Lenczyk, 1965). During the 1960's

interest in predicting the behavior of individual icebergs increased for a number of reasons. Firstly, IIP now had confidence that aircraft could spot and position icebergs reliably over wide areas during periods of good weather. Since the lack of good weather has been a severe problem, a means to predict the position between sighting is needed. Secondly, even with accurate drift prediction, the iceberg's rate of deterioration must be estimated so that it will not be carried on the ice plot for much more than a day after it has melted, or worse be eliminated from the ice plot prior to melting.

The answers to these questions of drift and deterioration prediction require that many individual icebergs be studied over an extended period of time. These studies require that the researcher be certain that he is working with the same icebergs and not one of several other icebergs that may be in the same area. Early attempts to mark icebergs made use of dye to color the sides of the iceberg. Kollmeyer (1966) used test tubes filled with various dyes and shot them on an arrow from a bow to mark a position on the face of an iceberg. This mark was used as a reference during a deterioration study. Over the years the IIP aircraft have repeatedly "bombed" icebergs with dye to aid in their identification.

Dyeing icebergs has limited utility because the rolling and melting of the iceberg soon washes the color away. Dye has a life of one to two days depending on the weather conditions and melting and rolling of the iceberg.

In 1974 the Coast Guard Oceanographic Unit (CGOU) began a project to determine the best way to tag an iceberg for identification and relocation. The first approach taken was to encircle an iceberg with a floating line (Hayes et al., 1975). The 0.95-cm line made of polypropylene was provided with additional flotation along its length (Figure 1). Radar reflectors and a Radio Direction Finder (RDF) transmitter were included as elements in the line.

Two tagging attempts were made using this method. On the first attempt three icebergs were tagged. The tagging arrays were carried away in a storm and only one was recovered. The line on the recovered array was broken in two places. One break occurred with such force that the ends of the fibers were fused; there was no evidence of chafing. The other break appeared to be the result of chafing. The second attempt had quite different results. The weather was fairly calm and several icebergs were tracked in dense fog for nine days. However, the tagging arrays slipped repeatedly over or under the icebergs. This necessitated early recovery of the equipment which drifted away from the iceberg although the line circle remained intact. This result was completely unexpected and probably resulted from the iceberg snagging the line and rolling out of the loop (Hayes et al., 1975). It should be remembered that these icebergs were in an advanced stage of deterioration and quite likely to roll.

A similar tagging experiment was carried out in 1976 (Brooks, 1977). After consultation with the Coast Guard, he used a much heavier line (24mm, polypropylene). Since the experiment was conducted at nearly 60°N, the icebergs could be expected to be more stable. The array was tracked using the NIMBUS-6 satellite system, but no attempt was made to verify whether the iceberg remained with the transmitter. The transmitter was not recovered.

3.0 ICEBERG TETHER

The development of an instrument package system which can be attached to an iceberg requires the solution to three problems; (a) iceberg rolling, (b) iceberg melting, and (c) iceberg calving. In 1975 the Coast Guard Research and Development Center (R&DC) tried a new approach to tethering an instrument package to an iceberg. This new approach used a large steel dart with a trailing line which attached to a floating instrument package. This method provides a solution to the problem of rolling and melting but not calving. It is not likely that any system can survive calving since the anchoring piece of ice would drift away rapidly from the iceberg itself, or any conceivable line would be parted by the weight of several hundred tons of ice falling from the side of the iceberg.

The dart was designed by applying the relatively new branch of dynamics called terradynamics which is the study of the forces acting on a body in relative motion to solid materials. After several trials, which included about two dozen drops, the present design was arrived at. The requirements were that it be easy to ship and assemble, cheap to build, and have stability and penetration for low altitude drops. The dart was manufactured from 5.72-cm cold rolled steel and 2.54-cm steel rod (Figures 2 and 3). It weighs 13.64 kg and has a 46-cm tail assembly of extruded high density polyethylene (Figure 4).

Using the equations developed by Young (1972), it was possible to calculate the approximate depth of penetration of a steel dart in glacial ice. The empirical equation was:

$$D = 0.0117\ K\ S\ N\ \sqrt{W/A}\ (V - 30.48)$$

for impact velocities of greater than 61 m/s. Where:

D = Depth of penetration, m
K = Scale factor, dimensionless
S = Index of penetrability, dimensionless
N = Nose performance coefficient, dimensionless
W = Dart weight, kg
A = Cross-sectional area, cm^2
V = Impact velocity, m/s

The dart was attached to 300 meters of floatable polypropylene line with a small section of cable to reduce chafing. With this length of line, the line will still be leaving the aircraft after the dart has hit, for a drop from 60 or 90 meters altitude. This results in the line laying smoothly on the surface and with little or no pull on the instrument package. The instruments can then be allowed to free-fall or be lowered by a parachute.

The line was originally placed on a faking board similar to those used with a Lyle lifesaving gun in the late 19th and early 20th centuries (Figure 5) (Lyle, 1878). The board was mounted vertically on the lowered rear ramp of a C-130 aircraft in flight. Over 300 meters of line feed off the board in less than five seconds. Stress problems developed with the board concept when

the bottom layers were reached. A much improved method of deploying the line was developed by Farmer (1977) (Figure 6). In this package, the line was packed in bundles secured by rubber bands. All of the bundles were then placed in a parachute pack. The parachute pack was opened when the dart was thrown from the rear ramp of the C-130 and the bundles smoothly unravel one at a time. The instrument package can then be launched just before the last of the bundles unravel.

A final instrument package has not been developed for the tagging system. In tests we have used a modified sono-buoy as an expendable transmitter.

4.0 TEST RESULTS

In addition to two tests involving a total of ten drops on icebergs, one test in 1975 and one in 1977, a number of tests of the system have been conducted over land at the Coast Guard Elizabeth City Air Station. The results of these tests are as follows:

(a) Accuracy - Coast Guard pilots are capable of hitting an iceberg as small as 20 meters on a side 75 percent of the time from 61- or 91-meter altitude after several practice runs.

(b) Line Handling - The parachute pack line-handling system developed by Farmer (1977) does a superior job of deploying large quantities of line without kinks or tangles.

(c) Penetration - The dart which was used in the tests on icebergs in 1975 and 1977 had a predicted penetration characteristic as given in Table 1 (Young, 1972).

TABLE 1

DROP ALTITUDE	IMPACT VELOCITY	IMPACT ANGLE (WITH THE VERTICAL)	PREDICTED PENETRATION
61 m	76 m/s	62°	0.93 m
91 m	80 m/s	58°	1.01 m

The drops were made from 61 meters at an airspeed of 130 knots (67 m/s) and ice was assumed to have an index of penetrability of 2.5. The 1975 test gave a penetration of 1.1 meters and the 1977 test (Figure 7) had a penetration of 0.76 meters. Other penetrations of the iceberg were not accessible from a small boat or were under water.

Holding Strength - The holding power of the 1977 test with 0.76-meter penetration exceeded the strength of a 1.25-cm polypropylene line which is approximately 5000 pounds.

Further development of an expendable instrument package is planned permitting the tracking of icebergs both from the surface and from satellite.

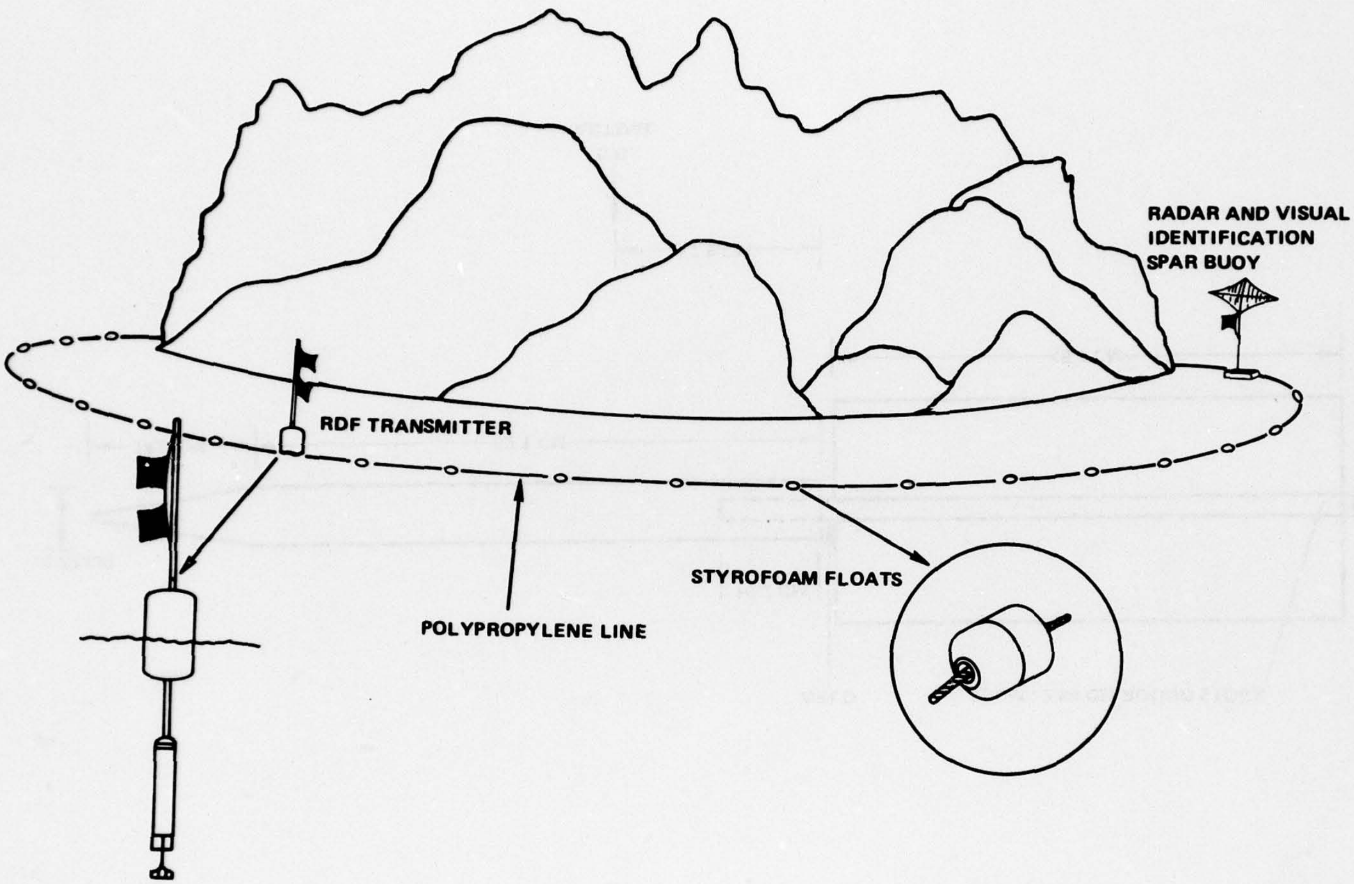

FIGURE 1

AN ICEBERG TAGGING SCHEME USING A FLOATING-LINE TECHNIQUE

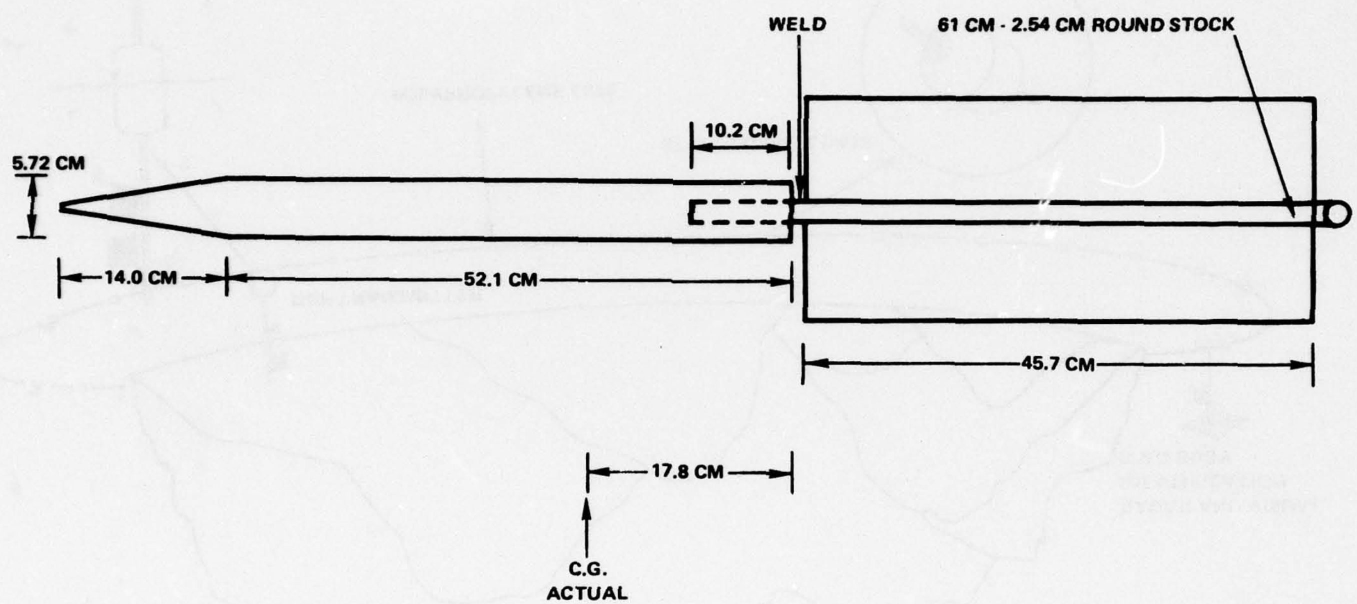

FIGURE 2

ICEBERG–TETHERING DART

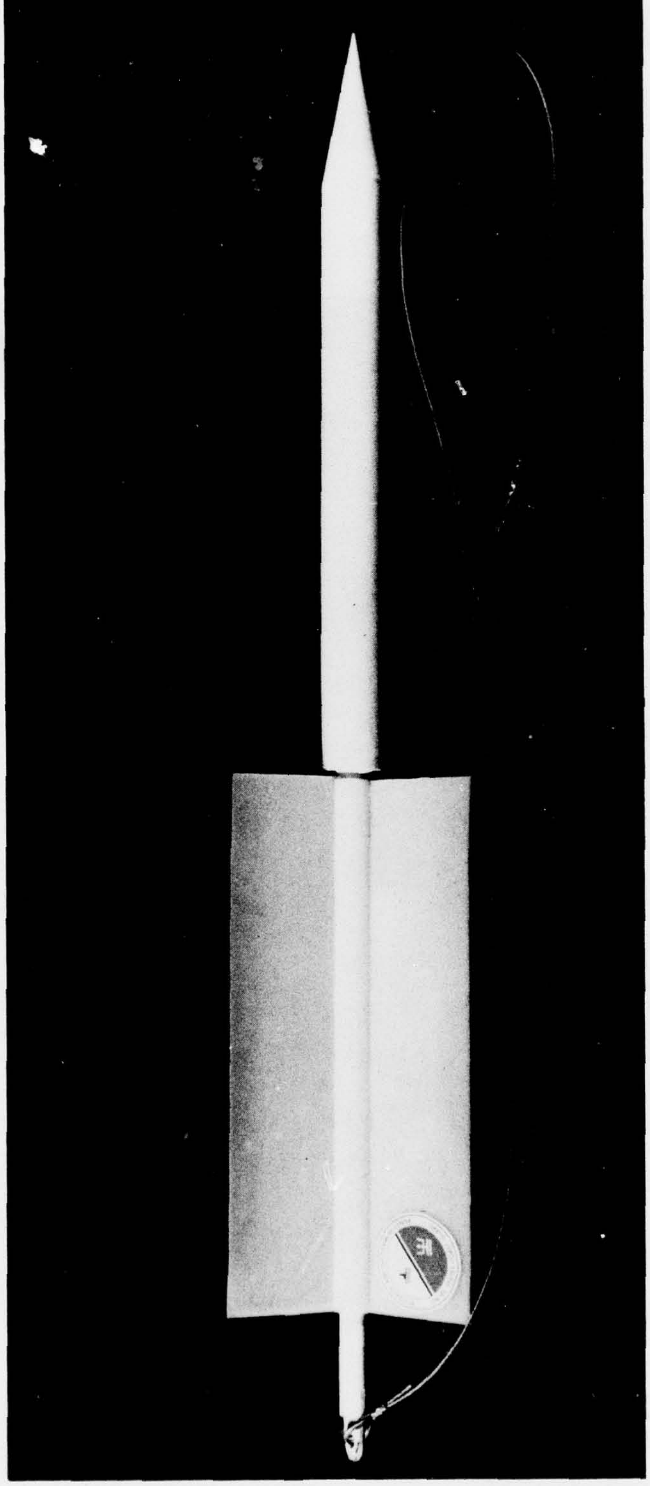

FIGURE 3

ICEBERG-TETHERING DART

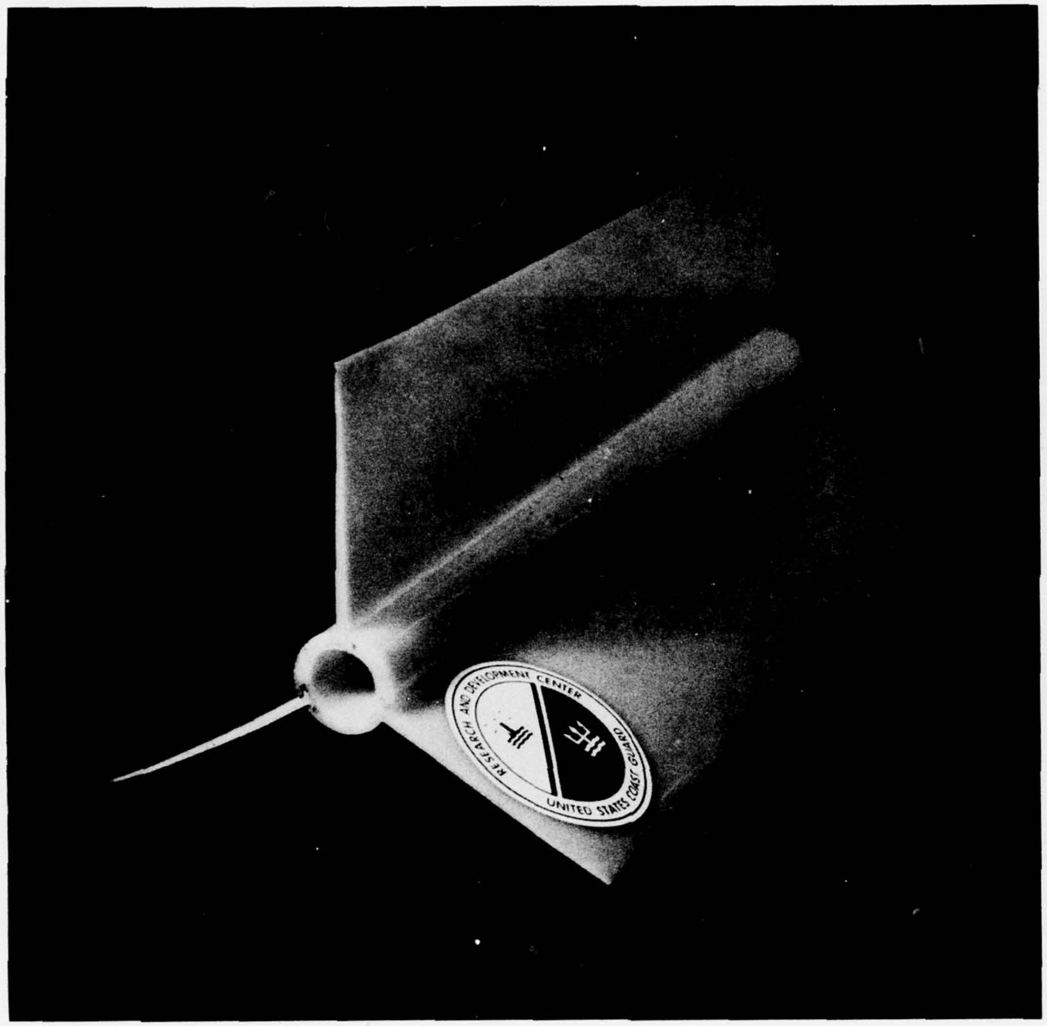

FIGURE 4

THE FOUR-PIECE EXTRUDED ICEBERG-TETHEING DART TAIL ASSEMBLY

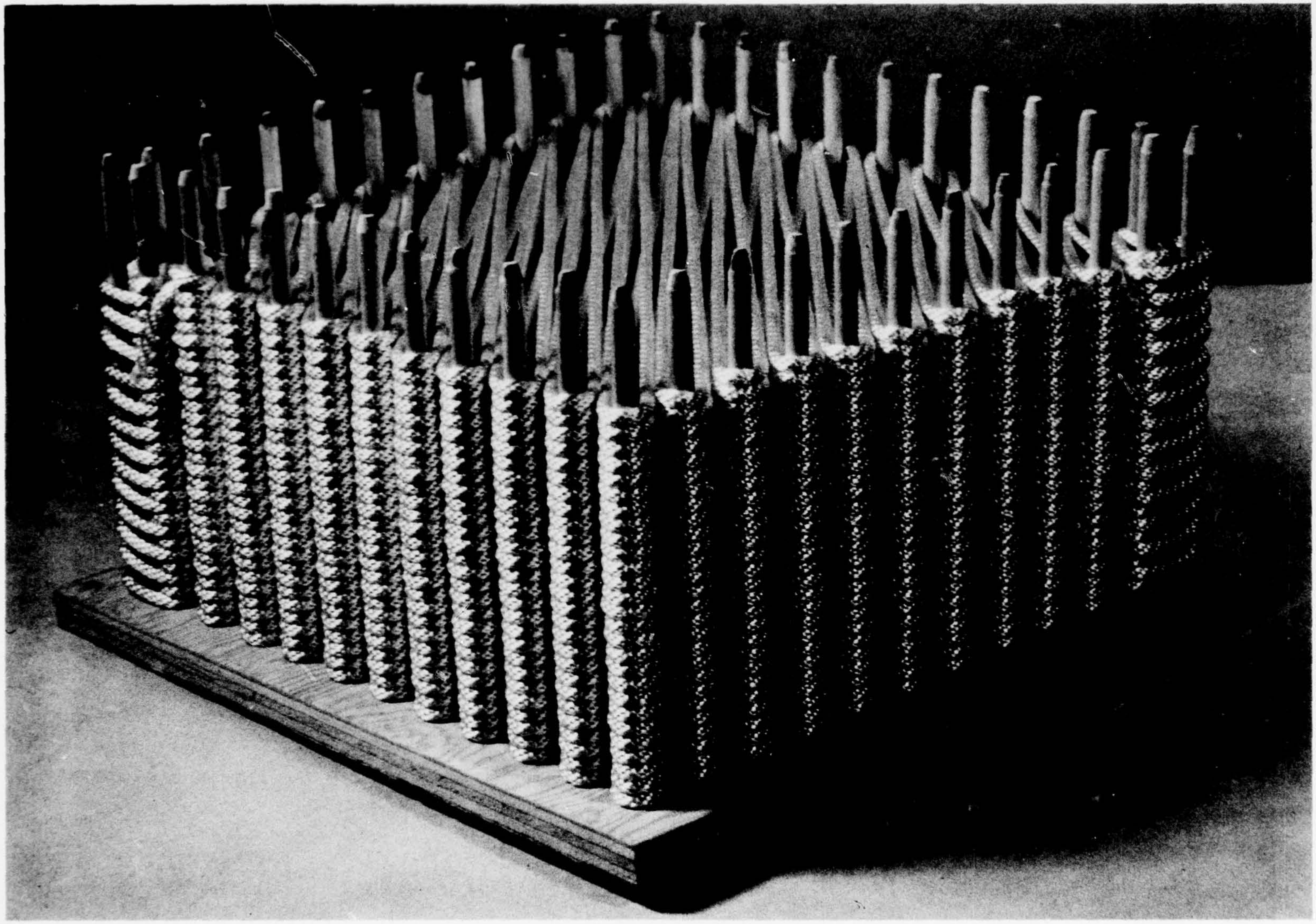

FIGURE 5

LINE FAKING BOARD

FIGURE 6

TRAILING LINE PACK

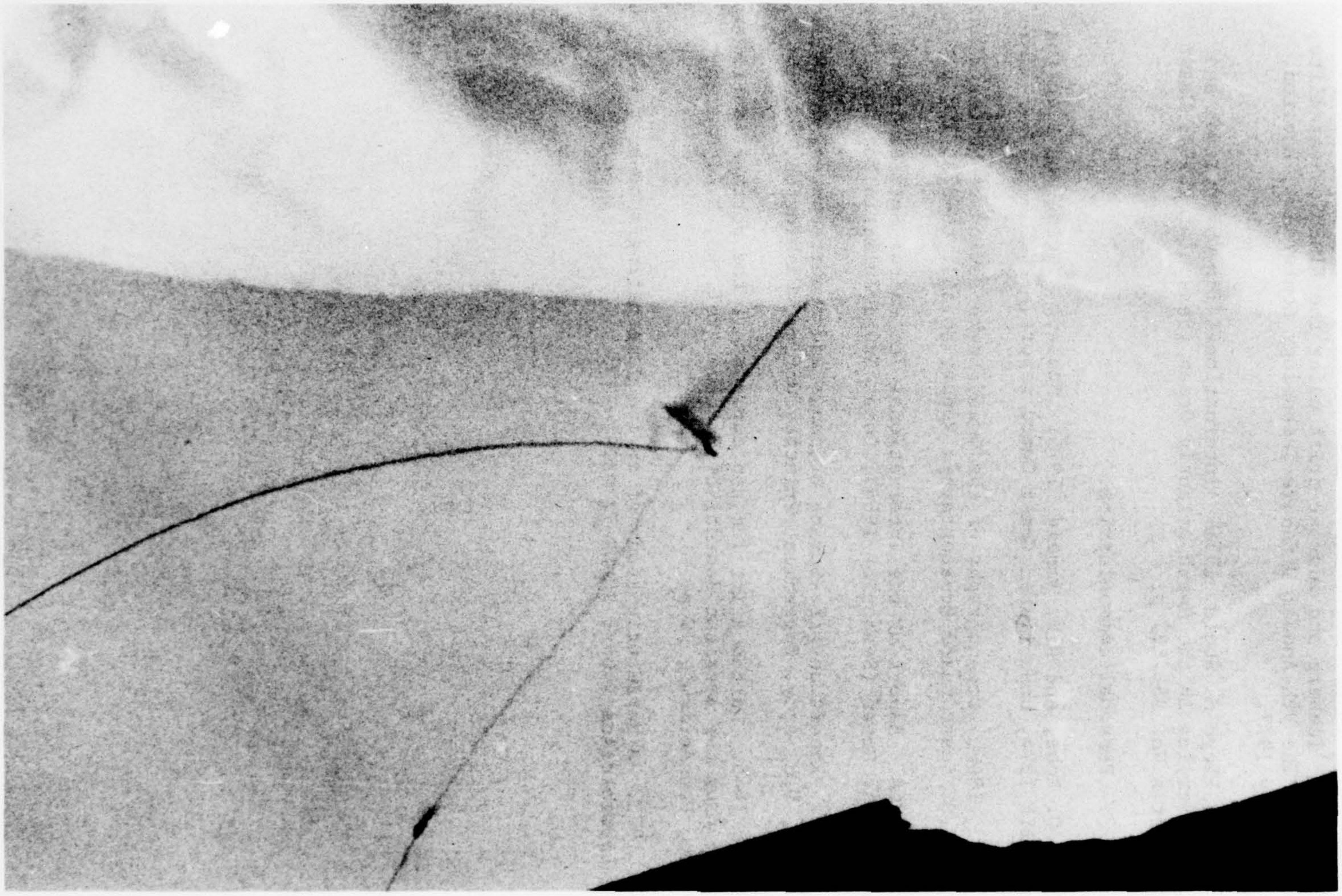

FIGURE 7

ICEBERG TETHERING DART IN THE SIDE OF AN ICEBERG, 1975 TESTS

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